(1) the series of vertical loops **61** of FIGS. 2–4 for electromagnetic suspension of the train body; (2) the two series of top and bottom horizontally disposed conductor loops **63T** and **63B** of FIGS. 5–7 for horizontal stability of the train body; and (3) the two series of very long horizontal and vertical loops **65H** and **65V** of FIGS. 8–10 for respectively imparting horizontal and vertical damping of oscillations and perturbations in the moving train. As stated in connection with the discussion of FIGS. 5–7, either the top or bottom series of horizontal stability loops, **63T** or **63B**, could be omitted, if desired, since a single set of figure-8 loops could provide an adequate amount of restoring force for horizontal stability of the train.

FIGS. 12–14 show an alternate form of the lifting track loops for vertical suspension of the train. Instead of having the lifting track loops disposed vertically, as in the embodiment of FIGS. 2–4, a horizontal arrangement of spaced, small conductor loops **61'** is employed. The array **61'** on each side of the track bed is formed of a longitudinally extending series of shorted loops having top and bottom half-sections **61'T** and **61'B** sandwiching the train super-conductor loops **55**. The respective half-sections of a loop **61'** are cross-connected to each other (as shown in the detail view of FIG. 12A) so that current induced in the upper half **61'T** are opposite in direction to those induced in the lower half-section **61'B** of each track loop. Thus the net magnetic flux, induced by the loops **55** of the passing train, is zero in each of the track loops **61'** when the train loop is horizontally aligned midway between the two half-sections of a track loop. However, a small vertical displacement of the train due to gravity produces, as before, an unbalance in the magnetic flux from the train loop which is coupled to the track loop so as to induce a sufficiently large circulating current to generate a restoring magnetic field which couples to suspend the weight of the train at an equilibrium position *e* slightly beneath the track loop's horizontal centerline of symmetry *h*. Although this alternative lifting loop arrangement has the same suspension efficiency (i.e., lift per unit track current) as the previously described arrangement shown in FIGS. 2–4, it requires that the lifting track loops **61'** be crowded into the same horizontally extending flange portions of structure **70** as that containing the horizontal stabilizing and damping loop arrays.

FIGS. 15–17 show an alternate form of track loop array for imparting horizontal stability to the electro-magnetically suspended train. In this alternative arrangement the horizontal stability track loop array **63'** for each side of the track bed is in the form of two longitudinally extending series of spaced vertically disposed loops. The top and bottom series of loops **63'T** and **63'B**, which are electrically separate from one another, are each formed of relatively small shorted conductor loops. Typically, as shown in the sectional view of FIG. 16, the bottom series of track loops **63'B** in the horizontal stability track array would be buried in the ground beneath the roadbed **25**. The series of top track loops **63'T** would then be carried in the track supporting structure **70**. Structure **70** would be modified somewhat to accommodate the vertically extending loops.

As in the case of the horizontally stabilizing track loop array described in connection with FIGS. 5–7, the position of the series of top and bottom track loops, **63'T** and **63'B**, in the left and right tracks serves to establish a predetermined horizontal equilibrium position for the respective train superconductor loops **55**. At this equilibrium position, no net horizontal restoring force is produced. This condition exists so long as the conductor elements of the train superconductor loops remain symmetrically spaced about the vertical plane of the stabilizing loops.

FIGS. 18–20 show still another form of track loop array combining both suspension and horizontal stability in an arrangement which does not require any supporting track structure projecting above the roadbed. Vertical suspension of the train is provided by a longitudinally extending track array on each side of closely spaced horizontally disposed loops **61''**. Individual loops are of short length relative to the train loops **55**, and have a lateral dimension which is substantially equal to the corresponding dimension of the train loops **55**. The array of track loops **61''** are positioned at or slightly beneath the surface of the roadbed **25**. When the train is in horizontal equilibrium, the track loops are directly beneath the corresponding train loops.

Horizontal stability of the train is provided by a longitudinally extending array on each side of closely spaced vertically disposed loops **63''**. Loops **63''** are substantially the same longitudinal length as the lifting loops **61''**. As best shown in the front sectional view or FIG. 19, loops **63''** may be buried in the roadbed and positioned along the middle of the lifting track loop array **61''** so as to define a vertical plane *v''* on each side of the track bed. The center of the respective train loops **55** will be in horizontal equilibrium position, with respect to plane *v''*, in which no current is induced in the horizontal stability loops **63''** by the superconducting magnets. From the discussion accompanying the preceding track loop embodiments, the manner of operation in which the respective track loop arrays **61''** and **63''** provide electromagnetic suspension and stability according to the present invention is understandable without further elaboration. A mathematical analysis, based partly on theoretical principles and partly on empirically derived data, of the operating characteristics for a magnetic train suspension system constructed according to the embodiment of FIGS. 18–20 is set forth in an article by the present inventors published by the American Society of Mechanical Engineers as Report No. 66–WA/RR–5 and presented at the Winter Annual Meeting and Energy Systems Exposition of the ASME, Nov. 27–Dec. 1, 1966. It is the intent of the inventors that the entire disclosure of this ASME publication be incorporated by reference into the present application as if the former document were fully set out herein.

In certain of the lifting track loop arrays described in the foregoing embodiments it is possible that, due to the strong coupling of the magnetic flux from the train loops with that of the track loop arrays, too large an induced current might flow in the lifting track loops. FIGS. 21 and 22 show a circuit schematic of one exemplary means for limiting the amplitude of this induced current, in the lifting track loop array, through the use of diode-connected external inductors. As schematically represented in FIG. 21, in a longitudinally-extending array of lifting track loops **61''**, one for each side of the track bed, an external inductor element is coupled in series with each individual track loop so as to increase the loop's impedance and in that manner limit its current.

In order to reduce the number of inductors, the individual loops **61''** may be arranged in a plurality of *n* groups, with the loops in a given group parallel-connected together through respective unidirectionally conductive means, e.g., diode means to a single inductor element. Thus, in FIGS. 21–22, every seventh loop along the length of a track side R is parallel-connected together to a single inductor element. A typical loop connection for a group of loops, as shown in FIG. 22, would couple together every seventh loop, starting from the fifth numbered loop in the sequence of seven, so that loops $5R_1, 5R_2 \ldots 5R_n$ would be grouped together and parallel-connected through diodes to an associated inductor I_{5R}. The pair of diodes connecting each individual loop to the inductor element for the group is arranged so that current will flow in that particular track loop, alone, when it is within the field of influence of the train superconducting magnets. The inductor element I_{5R} cannot itself act as a transformer and circulate induced currents in the remaining loops of the group which are outside the field of the train magnets. The number of groups into which the track loops **61''** are assembled is selected to be large enough so that each